Great Lakes Water Levels

Keith Kompoltowicz
USACE Detroit District

Significant water level rises have occurred on the Great Lakes since the winter of 2013. In fact, after setting an all time record low in January of 2013, Lake Michigan-Huron rose 20 inches in the spring of 2013, nearly doubling its average seasonal rise. The 2014 seasonal rise of Lake Michigan-Huron could also be more than average. Lake Superior also nearly doubled its seasonal rise in 2013 and is poised to climb above its long-term (1918-2013) average for the first time since 1998. Water levels on the other Great Lakes also experienced significant rises in 2013 and could rise further in 2014. Conditions leading to the water level rises include a significant snowpack and heavy spring rains in 2013 and the extremely cold and snowy winter of 2014. This presentation will recap the conditions leading up to the record and extremely low water levels of late 2012 and early 2013, then highlight the conditions that lead to the rises in 2013 and 2014. In conclusion the latest 6 month forecast of water levels will be discussed.

Great Lakes Ice and Climate: From Research to Forecast

Jia Wang
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Ann Arbor, Michigan

Over the past six years (since 2007), GLERL and CILER team has studied Great Lakes ice and regional climate in response to global climate changes and how to transfer scientific research results into predictions of lake ice on the scales of several days to several months. It was found that both NAO and ENSO have linear and nonlinear impacts on lake ice, respectively, but neither of them solely dominates the Great Lakes regional climate and lake ice cover. The combined effects of both NAO and ENSO on lake ice provide high predictability skills using statistical regression models. The new findings were incorporated into a statistical regression model, which can project median-range lake ice cover only using projected NAO and Nino3.4 indices one to several months ahead. For the first time, fully-coupled Great Lakes Ice-circulation Models (GLIM) with both dynamics and thermodynamics have been developed at GLERL/CILER to simulate and investigate the lake ice variations on the synoptic, seasonal, interannual, and decadal time scales. The hindcast results were validated using in situ, airborne, and satellite measurements. The validated GLIM has been used since the 2010-2011 ice season to forecast Great Lakes ice cover concentration, thickness, velocity, and associated air-ice-sea variables for up to five days in advance.

Evaluation of Great Lakes Ice Model (GLIM) Real-time Ice Forecasts During the 2013-2014 Ice Season and an Introduction to the Great Lakes Ice Products Web Page

Jia Wang and Gregory Lang
NOAA/Great Lakes Environmental Research Laboratory
Ann Arbor, MI

Robert LaPlante and Christopher Mello
NOAA/National Weather Service
Cleveland, OH

David Radell
NOAA/National Weather Service
Eastern Region Headquarters

The Great Lakes Ice Model (GLIM) is an experimental numerical forecast model intended to improve the accuracy of Great Lakes ice forecasts and outlooks, open lake forecasts, near shore forecasts and marine weather statements. The GLIM has been under development since 2007 and this presentation is mainly an update of the model and verification since the 2012-2013 ice season. The GLIM is run on all five Great Lakes twice per day as part on the Great Lakes Coastal Forecast System (GLCFS) at NOAA's/Great Lakes Environmental Research Laboratory (GLERL) (http://www.glerl.noaa.gov/res/glcfs). The GLIM is a combination of the Princeton Ocean Model for hydrodynamics and the Combined Ice Ocean Model (CIOM) ice model specifically tailored for operation in the Great Lakes. The combined lake circulation/ice model is run using the latest NWS National Digital Forecast Database (NDFD, http://www.nws.noaa.gov/ndfd) surface meteorological grids as input. Twice-a-day forecasts extend out to 5 days. The GLIM initial conditions are nudged toward a daily National Ice Center (NIC) ice concentration analysis. The integration of the GLIM and the NDFD forecast elements generates graphics showing surface water temperature, ice concentration, ice thickness, and ice drift and vessel icing potential. For verification purposes, the GLIM forecasts of ice concentration fields are compared to daily ice concentration analyses produced by the NIC.

In addition, this presentation will introduce a Great Lakes Ice web page created by the NWS Weather Forecast Office in Cleveland, OH (http://www.weather.gov/cle/greatlakesice). The web page contains the NIC ice analysis, GLIM ice forecasts, GLERL ice cover climatology, and satellite data to assist federal and commercial interests on the Great Lakes with navigational decisions.

LIDAR-based measurements of wind characteristics within the marine boundary layer over Lake Michigan

Frank J. Marsik[1], Neel U. Desai[2], Aline Cotel[1], Guy Meadows[2] and Kyle Chudler[1]

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The accurate characterization of the mean vertical profile of wind within the marine boundary layer (MBL) is critical given its relation to shear stress, a driving force in the generation of wind-driven waves and currents, wind loads on marine structures, and wind resource potential for off-shore wind energy generating systems.

For the Great Lakes region, a thorough assessment of the vertical profile of the mean horizontal wind speed and turbulent kinetic energy within the MBL has been hampered by the relative lack of wind measurements over the lakes. While an extensive network of buoy-based measurements have created a climatological picture of surface winds over the lakes, very little data exists regarding the nature of wind speed, shear and gust variations with height. Early studies focused on the characterization of MBL winds over the Great Lakes involved tower-based efforts, such as those by Davidson (1970) and Schwab et al. (1980). The measurements performed by Davidson were typically at 1, 2, 4 and 15 m above water level, though not all four heights were used for each measurement period. The measurements of Schwab et al. (1980) were performed at two levels (5 m and 10 m above water level).

Recently, a buoy-based LIDAR wind profiler (AXYS Laser Wind Sensor) was deployed over two locations within Lake Michigan (mid-lake plateau and 6km off coast near Muskegon) for extended periods during calendar years 2011-2013. This paper presents preliminary results from these measurements and represents the first extensive characterization of the vertical structure of the mean and turbulent components of the winds within the Lake Michigan MBL at heights representative of current design heights for offshore wind turbines. As such, this study represents a unique opportunity to obtain a better understanding of the potential for offshore wind energy development in the Great Lakes region. Additionally, this data set has the potential to contribute to other areas of study, such as the surface water transport of pollutants and the onset of coastal hazards such as structural currents and rip currents.

Beach Water Quality Forecasting: NOAA/NWS/GLERL NWS - Chicago/Detroit

David L. Beachler
NOAA/National Weather Service
Chicago, Illinois

Every beach season, beachgoers flock to the Great Lakes in search of relaxation and a suntan. For those that swim within the shallow waters of the lakes, swimmers are exposed to small concentrations of bacteria. While most do not react to these concentrations, there are times when bacteria growth is accelerated due to various meteorological conditions. The resultant exposure to poor water quality increases the risk of illness. For the past two seasons, NOAA/NWS has been generating an Experimental Beach Water Quality Forecast for various beaches in Lower Michigan. This initiative was expanded to include the Chicago Park District Beaches on Lake Michigan for the 2013 season. This talk will present the National Weather Service Forecast Office operational issues on making available 48 hour forecasts, and how we might move forward on integrating our services into the health sector.

Link: http://www.crh.noaa.gov/lot/?n=beachwaterquality-Chicago

Great Lakes Beach Hazards: A summation of efforts from WFO Grand Rapids

Bob Dukesherer
NOAA/National Weather Service
Grand Rapids, Michigan

A significant drowning threat exists along the beaches of Western Lower Michigan from a variety of beach hazards. An overview of the hazards will be presented as well as an explanation of forecast techniques. Decision support services will be discussed as to how the threat is conveyed to key user groups. Finally, collaborative efforts with the NOAA Coastal Storms Program will be detailed.

Sociological Factors Impacting Beach Attendance: Applications to Beach Hazards Risk Communication

Megan Dodson
NOAA/National Weather Service
Marquette, Michigan

The Great Lakes Current Incident Database (GLCID) is a twelve year archive of Great Lakes current related fatalities and rescues collected by the National Weather Service in Marquette, Michigan in order to understand the weather and wave conditions that lead to dangerous current development. GLCID statistics, lifeguard observations, and seasonal climate summaries are compared to beach attendance statistics from Michigan State Parks and Great Lakes beaches to identify the sociological factors that increase beach attendance and the risk of a current or wave-related incident occurring. National Weather Service forecasters, media personnel, and others involved in beach hazards risk communication efforts can use these factors to make effective operational decisions on when to highlight high swim risk days to the public.

Meteorological Tsunamis in Great Lakes

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4 University of Michigan Water Center

Meteotsunamis (or meteorological tsunamis), are propagating water waves generated by a moving atmospheric disturbance that share many similarities with seismic tsunamis observed in the ocean. In the Great Lakes, there have been several incidents of *meteotsunamis*. The most vivid event occurred in 1954, when a 10 ft meter wave struck Chicago with 7 people reported dead. Just 10 days after this fatal event, another large meteotsunami hit Chicago, with some witnesses reporting more severe conditions than observed with the fatal wave of the prior days. In this talk, we investigate these two large meteotsunamis to reveal the causative mechanisms of these devastating historic waves.. Furthermore we will show past and recent meteotsunami events with 7 feet waves caused by a strom cloude squall hauling across Lake Erie. We will also discuss Great Lakes meteotsunami occurrences from the past decade in to further examine the most favorable conditions for these dangerous waves The results of this study will help mitigate the risk of these destructive waves.

Evolving Marine Services in the Great Lakes

Michael Bardou and Eric Lenning
NOAA/National Weather Service
Chicago, Illinois

The National Weather Service director has established a vision for the agency as a science-based service organization. The services that originally prompted the creation of a federal weather agency were marine forecasts and warnings on the Great Lakes. The ongoing mission of the NWS is to provide accurate, timely, and effective weather information across a variety of program areas. Recent service-improvement efforts such as the Golden Triangle Aviation Initiative (GTI) and the Impact-Based Warning (IBW) program evaluated the need for and value of specific information and the process through which it is created and delivered. For marine services, much informal discussion has taken place with regard to challenges, gaps, and the effectiveness of marine forecast information on the Great Lakes. One result of this discussion is an ongoing outreach effort to the marine community to further identify where improvements to both the science and service side of the marine program can be made. This internal discussion and external user feedback have shed light on topics that could benefit from further evaluation and improvement. These topics include confusion regarding what products are expected to represent, inconsistencies within an office and among neighboring offices, proper use and interpretation of forecast products, and a means for tracking the accuracy and effectiveness of forecast services.

Apart from the informal discussion and periodic collaborations with Environment Canada, the NWS has not pursued a comprehensive, coordinated effort equivalent to the GTI or IBW process to evaluate existing marine services in the Great Lakes. The goal of this would be to improve both the accuracy and effectiveness of Great Lakes marine products on both sides of the border while reducing the manual workload required to produce them. Such a comprehensive effort would involve several steps:

- Identify exactly what information we wish to provide in our products, and how it needs to be communicated.
- Make sure every forecaster in every marine office is actually creating these same products.
- Agree on objective methods for tracking the accuracy of these forecast products.
- Identify ways to track the effectiveness of these products, likely through outreach efforts.
- Evaluate the efficiency of the product creation process vs product accuracy/effectiveness.
- Utilize verification statistics and user feedback to evolve these products and the process through which they are created.

These steps are cyclical in that continuous evaluation and tweaks may be needed, with customer needs and capabilities and scientific understanding and forecast creation methods changing over time. This presentation will encourage support for a unified, cohesive, ongoing effort to improve the accuracy and effectiveness of Great Lakes marine forecast services.

Reconstructing the Great Storm of November 1913

Richard Wagenmaker and Dr. Greg Mann
NOAA/National Weather Service
Detroit, Michigan

In November of 1913 the Great Lakes were struck by a massive storm system combining whiteout blizzard conditions and hurricane force winds. The storm lasted for four days, during which the region endured 90 mile per hour winds and waves reaching 35 feet in height. With only basic technology available, shipping communication and weather prediction systems were not prepared for a storm of such devastating force. When the skies finally cleared, the Great Lakes had seen a dozen major shipwrecks, an estimated 250 lives lost, and more than $5 million in damages (the equivalent of more than $117 million today).

Nicknamed the “White Hurricane”, the 1913 storm remains the most devastating natural disaster to ever strike the Great Lakes. One hundred years later, NOAA examined the Great Storm of 1913 not only for the pivotal role it plays in the history of the Great Lakes but also for its enduring influence. Modern systems of shipping communication, weather prediction, and storm preparedness have all been fundamentally shaped by the events of November 1913.

This examination leveraged the 20th Century Reanalysis Project to prescribe an adequate representation of “initial conditions” from which to generate a numerical retrospective. This study also leveraged the capabilities of the Weather Research and Forecast (WRF) modeling system to reconstruct atmospheric conditions; and the NOAA Great Lakes Environmental Research Laboratory Donelan Wave Model (GDM) to reconstruct the resultant sea state.

The main purpose of the simulation was to gain insights into the timing and severity of the conditions experienced by Great Lakes mariners. Of particular interest were wave conditions, as several large boats were caught unprepared for such extreme conditions. The GDM provides approximations for significant wave height (average of the highest ⅓), dominant wave period, and wind wave direction. As a companion calculation, an estimate of the average highest 5th percentile wave height from wave energy distribution is produced to characterize reasonably observed “peak” or “maximum” wave conditions. The return frequency of the peak wave is also calculated based upon the dominant wave period and the statistical occurrence of the average highest 5th percentile wave.

Bilateral Marine Forecast Collaboration Project

David Soroka
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Silver Spring, MD

In the summer of 2010 a bi-lateral collaboration document was developed by senior managers from the National Oceanic and Atmospheric Administration (NOAA) and Environment Canada (EC) to address improved marine service collaboration setting out a number of deliverables for the project. Over the next several months activities took place to analyze the alignment of services, creating stronger linkages in common training and working to improve inter-office coordination for cross-border issues.

In April 2011, NOAA and EC organized and held a workshop focused on marine forecasting. Representatives from weather offices from both meteorological agencies, the US National Weather Service (NWS), and Meteorological Services of Canada (MSC), met for one week in Seattle, WA to exchange information and discuss international marine weather collaboration. The meeting proved highly successful delivering a number of outcomes and recommendations that will serve as a basis for improved collaboration and cooperation.

The project renewal was accepted by the Collaborative Steering Committee (CSC) in spring of 2012, and the project document was updated in August of 2012. Phase 2 of the Marine Services Project reflected the recommendations for focus areas from the Area Leads to work toward an improved collaborative framework between NWS and MSC that will deliver more useful, consistent marine warning and forecast services to assist customers in risk assessment and the decision support.

During Phase 3, over the next 4 years, we will look to extend the reach of the project into new areas of remote sensing and service models as well as exploring unified forecast databases and improving collaborative training opportunities. In addition to the new areas of investigation, it remains a major goal of this project to move many of its successful Phases 1 and 2 deliverables into regularly occurring activities (operationalization) over the course of Phase 3. A measure of success with “operationalization” will be whether or not we are able to change the culture of both organizations to embrace the deliverables as Best Practices.

A new task we plan to undertake during Phase 3 will look to characterize the use of ensembles in the marine forecasting environment. In addition we will look to improve collaborative capabilities including a marine service portal, expand observational cooperation, as well as establishing a partnership with ongoing satellite proving ground activities.

Using Fractional Lake Ice and Variable Ice Thickness in the WRF-ARW to improve Great Lakes Forecasting

Michael Dutter and Todd Kluber
NOAA/National Weather Service
Marquette, Michigan

Most operational Numerical Weather Prediction (NWP) models (NAM, RAP, Canadian GEM) use a simple binary (0 or 1) for sea ice coverage input over water areas. In addition, ice thickness is assumed to be 3m in many operational NWP models. These assumptions can lead to significant errors of forecast latent and sensible heat flux off the lake surface, and as such can cause error in the NWP forecast of precipitation as well as other mass fields across the Great Lakes. To attempt to improve local NWP forecasts of the Upper Great Lakes during the Great Lakes "ice season", the NOAA/NWS Office in Marquette, MI, has configured the WRF-ARW V3.5.1 to ingest and process fractional ice information from the National Ice Center and ice thickness nowcast data from the Princeton Ocean Model for the Great Lakes (POMGL) Ice Model developed by the Great Lakes Environmental Research Laboratory (GLERL). Using several case studies from the 2013-2014 winter season as examples, we will show that the use of fractional ice and variable ice thickness can improve overall NWP forecasts for the northern Great Lakes.

A Simple Algorithm for Comparing Winter Storm Severity Based on METAR Observations

Daniel K. Cobb Jr.
NOAA/National Weather Service
Grand Rapids, Michigan

As part of the NWS's strategic goal of achieving a Weather Ready Nation - WFO-GRR prototyped a simple 5 color risk-based alert system to provide simple, clear, consistent, and actionable long-fused weather hazard information to a wide cross section of public safety officials including the Michigan State Police Emergency Operations Center during the 2013-2014 winter season. As part of this effort, a tool was developed to provide a consistent means to evaluate the relative severity of each winter storm over the season. The functionality of the tools is illustrated via several case examples.

Predictability Horizons:
Implications for Operational Forecasters

Justin Arnott
NOAA/ National Weather Service
Gaylord, Michigan

Richard Grumm
NOAA/ National Weather Service
State College, Pennsylvania

Experienced operational forecasters are well-aware that every high-impact weather system has a different level of predictability. It is also understood that modern ensemble forecast systems (EFSs) are frequently under-dispersive, with the eventual atmospheric solution falling outside the forecast envelope. One can think of the "predictability horizon" of the event as being the time in which deterministic and ensemble forecast guidance correctly "locks in" on a solution and when the solution no longer falls outside of the envelope of EFS forecasts.

In this study we examine two snowfall events that occurred over the Great Lakes region during January and February, 2014. It will be shown that the predictability horizon varied significantly for these events. Implications for appropriate watch/warning/advisory lead times will be discussed. In addition, variations in the predictability of different spatial and temporal scales of an individual system will be discussed, including precipitation start/stop times, gradients and precipitation types. A conceptual model describing weather system predictability will be presented, as well as a hypothesis on factors that may govern the predictability horizon of a particular event.

The December 8, 2013 Milwaukee, Wisconsin Lake-Effect Snow Band – High-Impact Weather Events Can Come In All Forms

James Wood
NOAA/National Weather Service
Milwaukee/Sullivan, Wisconsin

A lake-effect snow band developed during the middle morning hours on Sunday, December 8, 2013 south of the Milwaukee metropolitan area. This band moved northward into and through the Milwaukee area during the middle to late morning hours on December 8. It produced heavy snowfall rates of 1 to 2 inches per hour as it moved through. The heavy snowfall rates during this period caused several vehicle pileups across the major highways in the Milwaukee area. These pileups resulted in three fatalities and numerous injuries. Most of the major highways in the Milwaukee metropolitan area were closed for several hours due to the pileups occurring over a short period of time.

This presentation will explore the mesoscale details that led to the formation and intensity of the lake-effect snow band. It will also examine the impact of this lake-effect snow band on vehicles traveling during that time, and why so many vehicle pileups occurred. It will conclude by discussing how these types of high-impact events can be communicated by the National Weather Service to the public, in accordance with Weather-Ready Nation initiatives.

Wintertime Mesoscale Vortices and Adjoining Single Bands over Lake Michigan

Sam Lashley
NOAA/National Weather Service
North Webster, Indiana

Jon Hitchcock
NOAA/National Weather Service
Buffalo, New York

Lake effect snow events across the Great Lakes are generally classified into five different categories based on snow band orientation to the wind and the long axis of the lake on which they form. Type I single bands are well known for their intensity and ability to produce snow that is often measured in feet rather than inches. Type IV events are less intense shore parallel bands that occur from land breeze convergence caused by very cold air and generally weak gradient winds. Type V mesoscale vortex events develop under atmospheric conditions similar to Type IV bands and have also been shown to rarely produce substantial snowfall. However, mesoscale vortices are often viewed as spectacular and intriguing based on their appearance in satellite and radar imagery. On occasion, a mesoscale vortex will form in tandem with either a Type I or Type IV single band over the northern half of Lake Michigan and propagate southward. When moving onshore, these joined features have produced intense snowfall rates and dangerous white out conditions. This behavior does not fit within any of the previously documented lake effect categories and has been deemed the Lashley-Hitchcock Type VI snow band. This presentation will look at the synoptic and mesoscale conditions conducive for the formation of a Type VI snow band while showing several cases of its development. Forecast implications and societal impacts will also be discussed, including the January 23rd, 2014 vehicle pileup which occurred on Interstate 94 near Michigan City, Indiana during one of these Type VI snow events.

Diagnosis and Near-Term Forecasting of an Intense Mesoscale Snowband February 2nd, 2014

Nathan Marsili
NOAA/National Weather Service
North Webster, Indiana

During the early morning hours of February 2nd, 2014, a mesoscale snow band produced a narrow swath of 5 to 8 inch snowfall accumulations across northern Indiana and northwest Ohio. Snowfall rates as high as 2 to 3 inches per hour were reported. Several synoptic and mesoscale factors combined to produce the mesoscale banding which will be discussed. A positively tilted upper level trough tracked across the Great Lakes which resulted in the stalling low level baroclinic and a period of enhanced low and mid-level frontogenesis. An ingredients based approach will be presented which increased situational awareness as to the potential of mesoscale banding during this event, primarily by highlighting an area of reduced mid-level stability in vicinity of the low level baroclinic zone. The frontal circulation was also enhanced by strong upper level jet dynamics.

Model forecasts from 18 to 24 hours prior to the event depicted the low level baroclinic zone and more pronounced midlevel instability shifting just to the south of the NWS Northern Indiana county warning area by the late evening of February 1st. As the upstream short wave became better resolved by 00Z, the majority of short-term guidance trended further north with the resultant downstream frontogenesis forcing, along with a northward displacement of an axis of reduced mid-level stability. During this event, an ingredients based approach of interrogating model depictions of forcing and instability provided forecasters with an indication as to the potential of mesoscale banding. However, the mesoscale nature of this event required high forecaster situational awareness regarding the impact of slight errors in short-term model initializations on favored areas of intense mesoscale banding.

Towards a Simple Risk Based All-Hazards Warning Paradigm

Daniel K. Cobb Jr.
NOAA/National Weather Service
Grand Rapids, Michigan

As part of the NWS's strategic goal of achieving a Weather Ready Nation - WFO-GRR prototyped a simple 5 color risk-based alert system to provide simple, clear, consistent, and actionable long-fused weather hazard information to a wide cross section of public safety officials including the Michigan State Police Emergency Operations Center during the 2013-2014 winter season. Its potential as an All-Hazards National Disaster Alert System is described and compared to the current NWS Watch-Warning-Advisory system.

Stop Speaking to Ourselves: Using Plain English, Simple Graphics and Message Control to Build a Weather Ready Nation

James Maczko
NOAA/National Weather Service
Grand Rapids, Michigan

This presentation will discuss how NWS Grand Rapids has taken lessons learned from the Incident Command System, the UK Met Weather Office, social science and media/graphical experts to reinvent how the NWS communicates significant weather information to the public, media and emergency management community.

An Examination of two Near-Blizzard Events across Northern Indiana in January 2014

Amos Dodson and Sam Lashley
NOAA/National Weather Service
North Webster, Indiana

Two near-blizzard events with very different synoptic settings impacted northern Indiana in January, 2014. On January 5th-6th, 2014, a strong mid-latitude cyclone passed through the Ohio Valley and spread 8-14 inches of snow across northern Indiana. The combination of heavy snow and strong winds gusting up to 40 mph led to considerable blowing and drifting snow. The second event, occurring on January 26th-27th, 2014, was associated with an arctic cold front. While new snowfall amounts were minimal, very strong winds gusting to 45 mph and a deep antecedent snowpack caused another round of reduced visibilities and areas of substantial drifting snow. The relevant synoptic and mesoscale processes involved with these events will be discussed. The frequency of blizzard and near-blizzard events across northern Indiana will also be placed into historical context by leveraging a local database of hourly surface observations dating back to 1940. The presentation will then culminate in a brief discussion regarding the challenges of impact based warning decisions during rare and high impact winter weather events that fail to meet National Weather Service thresholds for blizzard warning issuance.

Southern Ontario Ice Storm: Nightmare Before Christmas

Stephen Knott
EC/OSPC
Toronto, ON

From Dec 20 till Dec 22, 2013 southern Ontario and the GTA (Greater Toronto Area) was impacted by a major ice storm, possibly the worst ice storm to hit the GTA in recent memory. Roughly 600,000 customers or an estimated 1.5 million people were without power at some point during the aftermath of the storm, many without power for upwards of a week. Close to 20 percent of Toronto's tree canopy may have been damaged by the effects of ice accretion. The Environment Canada forecast prediction system performed very well in the identification of this event both in the long range and short range prior to the event. The Freezing rain storm occurred in two phases or moisture surges across a quasi- stationary arctic frontal system with the second surge resulting in the greatest impact to people. This presentation will explore the messaging of the OSPC (Ontario Storm Prediction Centre) in conveying the significance of the upcoming ice storm, the meteorological forecast challenges and the visualization of the event through the NinJo workstation.

Improving Lake Effect Snow Nowcasting and Quantitative Precipitation Estimation Using Synergistic Satellite and NEXRAD Products

Mark S. Kulie, Univ. of Wisconsin, Madison, WI; and Joleen Feltz, Andi Walther, Michael Dutter, Steve Nesbitt, Ralf Bennartz, and Andrew Heidinger

Lake effect snow (LES) in the Great Lakes region can produce prolific snowfall and is a hazardous weather producer, yet the NEXRAD network has observational deficiencies in certain locales due to the shallow nature of these convective snow events. In an effort to mitigate NEXRAD observational shortcomings for LES events, synergistic radar and satellite products are utilized to improve both LES nowcasting capabilities and remotely sensed snowfall estimates. Methods to extend NEXRAD coverage in regions that are frequently devoid of radar observations are being developed by first collocating NOAA Algorithm Working Group (AWG) satellite-based cloud products and NEXRAD-derived snowfall rates near Great Lakes radar sites to 'calibrate' AWG products for LES events. Empirical relationships between NEXRAD-derived snowfall rate and AWG cloud properties are then developed using this collocated dataset to enable snowfall rate estimates that are generated directly from AWG products, thus providing extended LES observational coverage to augment the NEXRAD network. Preliminary results from a combined satellite-radar dataset of winter 2012-2013 LES events will be discussed, and examples that illustrate the potential utility of this snowfall-related product will be presented.

Improving the Quantitative Precipitation Estimate for Dual Polarization Hydrometeors Classified as Dry Snow

Kirk R. Apffel, Aaron Reynolds and David Zaff
NOAA/National Weather Service
Buffalo, New York

Between 2011 and 2013, National Weather Service (NWS) operated Weather Surveillance Radar 1988 Doppler systems (WSR-88D) were upgraded with a dual polarization capability. The polarimetric upgrade is considered by many to be the most significant enhancement made to the nation's network since Doppler radar was first installed, with better information about precipitation type, intensity, and size. Much work has gone into improving quantitative precipitation estimates (QPE) for rainfall, but dual polarization radar uses a modified (pre-dual polarization) radar rain relation for hydrometeors classified as dry snow that applies a factor of 2.8 to take into account for lower reflectivity returns associated with dry snow.

NWS Forecast Office Buffalo, NY was upgraded with dual polarization during April 2012 and together with surrounding offices noticed an overestimation in QPE for several cold season events. A local study used 13 events with 383 separate gauge-to-radar comparisons to test the 2.8 coefficient and found that it was too high and led to a high bias in QPE. Until a more comprehensive dry snow relationship is developed, the study suggests a variable coefficient for dry snow should be used. When taking into account radar sampling and classification challenges for mixed precipitation, preliminary results suggest that the dry snow coefficient should roughly range between 1.3 and 1.7.

The 20-21 February Lake Enhanced Snow Event in Northern Lower Michigan: Forecast Challenges

Michael Boguth, David Lawrence, Brian Adam, and Justin Arnott
NOAA/National Weather Service
Gaylord, Michigan

A localized, high-impact lake enhanced snow event occurred across parts of northern Lower Michigan during the afternoon and overnight hours of February 21st, 2014. Snow amounts exceeded one foot in some of the interior highlands north of Gaylord, with snowfall rates approaching one inch per hour. The combination of heavy snow and gusty winds resulted in localized whiteout conditions with multiple roadway closures. Interestingly, this event was very poorly anticipated by all available numerical guidance, including operational and in-house high resolution models. This resulted in a low confidence forecast that anticipated snow totals significantly below what was observed.

This event was characterized by intensifying low pressure moving north across central Wisconsin into central Lake Superior, resulting in very gusty south and southwest winds across northern Lake Michigan late in the day on February 20th, continuing through the early hours of the 21st. These gusty winds resulted in rapid and unexpected deterioration of near record setting ice cover across northern Lake Michigan. It is hypothesized that this changing ice cover impacted the ability of operational guidance to correctly anticipate the magnitude of this event. In this study we will give an overview of the event, focusing on the potential mesoscale influences of Lake Michigan, its ice cover and the local terrain on snowfall location and magnitude, as well as snow microphysics.

Proposed Changes in the Winter Weather Forecasts at the Weather Prediction Center (WPC), and New Experimental Forecasts

Dan Petersen
NOAA/NWS/NCEP/WPC

The WPC product suite is constantly evolving in response to new customer needs and the increasing need for decision support. Proposed changes to WPC winter weather product suite are discussed in this presentation, as well as experimental winter weather forecasts for days 4-7.

The WPC produces probabilistic winter weather forecasts for snow and ice accumulation across the 48 contiguous states (http://www.wpc.ncep.noaa.gov/pwpf/about_pwpf_productsbody.html). The forecast models and ensembles used to derive the probability distribution include a large proportion of Short Range Ensemble Forecast (SREF) system members. Thus the quality of the probabilities are heavily dependent on skillful SREF forecasts. Situations in which the SREF did not verify as well as the global models will be shown, making the case to diversify the probability forecasts to include other ensemble systems, and provide less weighting to the SREF forecasts.

Probability forecasts for 2013-14 provided the potential for snow/freezing rain accumulations covering the entire 3 day forecast period for 24, 48, and 72 hour time intervals (http://www.wpc.ncep.noaa.gov/wwd/winter_wx.shtml). Since multiple forecast offices use 12 hour snowfall/freezing rain accumulation criteria for watch/warning decision making, forecasts probabilities for snow/ice accumulating in each 12 hour window are proposed to aid in the warning decision making process.

Also in 2013-14, the WPC conducted preliminary testing of an experimental days 4-7 forecast probability of snow and icing for 0.10 inches of liquid equivalent precipitation, with one forecast for each 24 hour period. The manually produced WPC Quantitative Precipitation Forecast (QPF) for days 4-7 was used, as well as temperature profiles from the global ensemble forecast system (GEFS) ensemble members. Samples of the forecasts and verification will be shown, addressing areas where improvements will be made. Like with the SREF in days 1-3, the plans for next year are to incorporate multiple model/ensemble systems. WPC will continue to test the days 4-7 probability forecasts leading into the 2014-15 winter season.

A Brief and Preliminary Summary of the Winter of 2013-2014 Across the Far Western Great Lakes Region

Linda Engebretson
NOAA/National Weather Service
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General public and media perception of the winter of 2013-2014 across the far western Great Lakes Region, including northern Minnesota, northwest Wisconsin, and western Lake Superior, has been that it has been an extremely long, cold and snowy winter across the region, with numerous comparisons made to many record-setting historically cold and snowy winters of the past. While this most recent winter season was certainly cold, with substantial amounts of snow, it was seldom record-setting in the traditionally thought of ways, such as the number of record minimum temperatures set, or record amounts of snowfall for a particular individual day, week, or month. Preliminary analyses seem to suggest that the winter was characterized more by a persistence of moderate to severe cold (but not extreme), which was also often accompanied by anomalously high surface winds, and only slightly above "normal" snowfall, but with little or no melting throughout the winter.

This presentation will explore many interesting aspects of the 2013-2014 winter across the far western Great Lakes Region, including analysis of the overall synoptic weather pattern and the phases of the various oscillations that seem to have influence on larger scale flow (i.e. ENSO, NAO, AO), and a look at the more traditional climatological measures of temperature and snowfall. However, we will also cover some of the other local and small scale impacts, such as 1) ice on both area inland lakes and Lake Superior, 2) frost depth and related impacts on infrastructure including frozen water mains, 3) persistence of the cold and the accompanying wind, 4) local Department of Transportation snow removal and road treatment budget overruns, 5) cumulative days off of school due to cold, 6) percentage of time with wind chill headlines in effect, and finally 7) some data from a newly developed winter season severity index.

A Study of Great Lakes Effects on Cold Season Synoptic Processes Using WRF Comparison Experiments

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Two synoptic events in late 2013 are studied with regard to the Great Lakes' effects on low system development by using the latest Weather Research and Forecast (WRF) Model. The first case is a deep low (DL) from 16 Nov to 18 Nov, corresponding to a Midwestern tornado outbreak; the second is a shallow low (SL) from 13 Dec to 15 Dec, corresponding to a broad-ranging snowfall in the Northeastern America. For the two processes, the community Noah Land Use Model in WRF is initialized in three different configurations: the control runs with real MODIS land use, the no-lakes runs in which the lakes are replaced by terrestrial land use, and the SST-lakes runs using high-resolution sea surface temperature analysis.

For the control runs, the WRF model exhibits a good performance in simulating the synoptic scale weather processes, for both the DL and SL. Comparisons between control runs and no-lakes runs show that the Great Lakes generally strengthen the low system near the surface. This process brings more precipitation in the near-lake region and constrains the precipitation in the off-lake area. The lake effect becomes much more significant for the development of SL and associated precipitation. During these synoptic events, the circulation and precipitation reveal less sensitivity to the varying SST, compared with the modified land use. Meanwhile, the remote effects of the Great Lakes tend to be subtle for both cases in our study.

Moisture Laden Inversions: Implications for Lake Induced Stratocumulus

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Arguably, the forecast of greatest frequency for the Great Lakes region involves predicting the development, persistence, or dissipation of lower tropospheric strata. The exercise routinely proves difficult with a considerable amount of consternation endured by operational meteorologists. Improved weather information with regards to this common forecast problem is important. Accurate forecasts aid flight planning and air traffic efficiency. Oftentimes, the existence or lack of low cloud plays a defining role in the modification of critical thermal profiles ahead of cold season precipitation events.

A collection of atmospheric research published recently has focused on mixed phase stratocumulus in the Arctic. While a main motivation behind the studies was to gain an increased understanding in the cloud processes to improve radiative schemes and the calculation of energy budgets for the arctic region, some key findings focused on moisture distributions important to the operational forecaster. First, it has been found in a number of studies that 50 to 70 percent of stratocumulus decks are supported in an environment in which saturation extends within the lowest 200 to 300m of the low to mid-level subsidence inversion. Secondly, recent literature has expanded upon the observation that specific humidity inversions or maximums can and oftentimes do occur above the base of the thermal inversion. This is in stark contrast to the significant lowering of relative humidity above the inversion base; a detail typically overlooked by operational forecasters. This presentation will offer results from a number of brief case studies linking these specific moisture distributions to stratocumulus events for the Great Lakes.

Revisiting the Joplin Tornado: Examining the Effectiveness of the Warning System

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One of the most devastating weather events in the nation's history impacted Joplin, Missouri when an EF5 Tornado took over 160 lives on May 22, 2011. Since then much has been studied and written about the event – seeking answers as to why so many died, the performance of the warning system, and what future steps can be taken to minimize loss of life from violent tornadoes.

This presentation aims to synthesize much of what we know about the disaster. This includes how the event unfolded meteorologically, how the community responded to alerts, and how the event has impacted the manner in which we approach the severe weather warning problem. This talk also will address some of the misperceptions that have come to exist concerning the Joplin tornado, and describe a way forward for the severe weather warning system.

An Evaluation of Mortality Rates Within the Path of Well-Warned Significant Tornadoes

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Since the National Weather Service implemented its modern warning infrastructure, a well-documented decline in tornado-related fatalities has been observed. The relatively few fatalities associated with recent significant tornadoes, such as the Greensburg, Kansas EF-5, have been oft cited as success stories of the National Weather Service warning system. However, the particularly high number of fatalities associated with the 2011 tornado season made it the deadliest such season in the United States in nearly 90 years. From various sources, doubt was cast upon the effectiveness of NWS tornado warnings, particularly those associated with the Joplin, Missouri EF-5, the deadliest single tornado to occur in the modern era. It is asserted in the present study that a failure to normalize the death toll by the size of the population directly impacted by the tornado results in a skewed perception that tornado warnings are more effective in regions of low population density. Further, using calculated mortality rate as a proxy for warning effectiveness, it is hypothesized that warnings associated with various significant tornadoes, including the Joplin EF-5, can accurately be viewed as similarly effective. In order to maximize confidence in the results, the above authors individually executed different methodologies using independent datasets to arrive at similar results. The methodologies, results, and implications are discussed here.

A Preliminary Environmental and Radar Overview of a Rare Early Morning QLCS Tornado Outbreak in East-Central Wisconsin on 7 August 2013

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A rare early morning tornadic quasi-linear convective system (QLCS) struck east-central Wisconsin shortly after midnight on 7 August 2013. This was the largest early morning tornado outbreak in east-central Wisconsin since 1950. The tornadic nature of this damaging early morning QLCS was not anticipated. During the evening several thunderstorm clusters extending from north-central through west-central Wisconsin congealed to where two large bowing segments formed over central and east-central Wisconsin by 05 UTC. The bowing segments organized within an increasingly supportive synoptic-scale setting characterized by an approaching shortwave trough, increasing deep layer shear associated with an unseasonably strong upper-level jet, weak low-level warm advection and low-level moisture advection. The setting within which the QLCS evolved could generally be categorized as a moderate shear and low instability environment. According to the SPC RUC-based mesoanalysis, 0-6 km shear values of 30 ms-1 and MLCAPE values around 500 Jkg-1 were representative of the pre-storm conditions.

Preliminary radar analysis indicated that the QLCS generated at least 13 mesovortices as it accelerated eastward across central and east-central Wisconsin. There appeared to be two phases of mesovortex development. The first phase occurred over central Wisconsin and the second phase a few hours later over east-central Wisconsin. Based on storm reports from Emergency Managers and the public, only wind damage occurred with the first phase while QLCS tornadoes occurred with the second phase according to NWS damage assessments. No formal damage assessments were conducted with the first phase. In both phases, a portion of the QLCS was observed to surge or pivot to an approximate north-south orientation, with the updraft-downdraft convergence zone (UDCZ) becoming orientated nearly normal to the 0-3 km bulk shear vectors. As the line segments pivoted, several mesovortices were observed to develop along the leading UDCZ. The position of the UDCZ along the immediate front edge of vertically-upright updrafts suggests that the system cold pool and environmental shear were approximately in balance along these line segments. This balance resulted in deep, upright updrafts which favor mesovortex stretching. The second phase of mesovortex development in this case was considerably more impressive, spawning at least six tornadoes of EF1 and EF2 intensity within about a 45 minute period. The tornadic mesovortices were observed to race eastward at speeds of 30 to 32 ms-1 (60 to 65 kts) in response to a mature rear inflow jet (RIJ). All known tornadic mesovortices evolved within a 30 mile wide corridor bounded by the apex of the bowing line segment to the south, and an E-W thunderstorm outflow boundary to the north. Preliminary radar and environmental analysis suggest all necessary ingredients for mesovortex genesis and strong intensification were present as described by Schaumann and Przybylinski (2012).

Possible factors that may have contributed to the rapid development and intensification of the tornadic mesovortices, including cold pool strength, the role of the RIJ and the E-W thunderstorm outflow boundary, will briefly be addressed. Given the climatological rarity of an early morning tornado outbreak in this part of the country, that fact that an impending tornado threat was not anticipated that evening, the rapid evolution of the tornadic mesovortices, and the extreme forward propagation speed of the QLCS, this event offered numerous short-term forecast and warning decision challenges.

Tornadic Debris Signatures (TDS) were also observed in the dual polarization (DP) data accompanying many of the mesovortices. TDS signatures associated with tornadic mesovortices embedded within a QLCS are not well documented. Thus, a preliminary description of the DP radar characteristics of some of the TDS signatures, as well as other possible debris signatures that did not appear to fit the definition of a true TDS will be presented in a companion paper.

QLCS Mesovortex Dual-Polarization Debris Signatures Associated with the 7 August 2013 Tornadic QLCS

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A quasi-linear convective system (QLCS) raced across Wisconsin during the late night and early morning hours of 6-7 August, 2013, producing wind damage and several tornadoes in east-central Wisconsin. Hundreds of homes, businesses and farm buildings were damaged. Thousands of trees and power lines were downed, leaving tens of thousands of people without power. Two minor injuries were also reported at a campground. Preliminary radar analysis indicated that the QLCS generated at least 13 mesovortices as it accelerated eastward across central and east-central Wisconsin reaching forward propagation speeds of 32 ms-1. Six of these mesovortices spawned tornadoes (5 EF-1 and 1 EF-2), with all occurring within about a 45 minute period beginning at 1230 am CDT on 7 August. All known tornadic mesovortices evolved within approximately 70 km (38 nm) from the National Weather Service (NWS) Green Bay WSR-88D Doppler radar, with 3 of these evolving within approximately 48 km (26 nm) of the radar. Many of the tornadic mesovortices were accompanied by dual-polarization (DP) tornadic debris signatures (TDS) at some point during their lifetime.

Mesovortex (MV) tornadic debris signatures embedded within a QLCS are not well documented. The relatively close proximity of tornadic mesovortex evolution to the NWS Green Bay radar afforded an opportunity to more closely examine DP characteristics of the accompanying debris signatures. DP correlation coefficient (CC) and differential reflectivity (ZDR) data were examined both vertically and temporally, and then compared to corresponding reflectivity (Z) and storm relative velocity (SRM) data associated with each tornadic mesovortex. Time-height sections of rotational velocity (Vr) and TDS depth were generated for each tornadic mesovortex to identify any relationships between QLCS tornadic mesovortex genesis and intensification to observed TDS characteristics. TDS depth was defined as the maximum height above ground level (AGL) in which a TDS was detected. A very preliminary analysis of the data indicated that a TDS typically first appeared within 1 or 2 volume scans (VCP12) after initial MV genesis. In all 6 tornadic mesovortices, the first TDS signature identified occurred either concurrently or a few volume scans before the maximum rotational velocity was reached in the SRM data. The average TDS maximum depth was approximately 2 km with the greatest observed depth reaching nearly 3.5 km. In half of the tornadic mesovortices, the maximum TDS depth was observed in the same volume scan where the TDS was first identified. The average maximum TDS depth of 2 km in this tornadic QLCS was nearly double the depth observed by Schultz et al. (2012) in their study of TDS signatures associated with weak (< EF-2) tornadoes. The preliminary observations described above should be considered somewhat tenuous for several reasons. It was very challenging at times to identify individual TDS signatures given the very close proximity of some of the tornadic mesovortices to one another, mesovortex mergers, very rapid mesovortex evolution, fast storm forward propagation speeds and ground clutter issues. In addition, some of the TDS signatures appeared to be embedded within broader areas of relatively low CC, especially later in the QLCS evolution. It was not clear if these broader areas of low CC were simply the result of the fanning out of residual debris from previous tornadic mesovortices, the lofting of less concentrated areas of light debris by the leading gust front or a combination of the two.

Analysis of the Devastating Cold Season November 17, 2013 Washington Tornado

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On November 17, 2013, a significant and anomalous cold season tornado outbreak occurred across Illinois, Indiana and western Kentucky. Numerous long track strong and violent tornadoes developed in the high shear and moderate CAPE environment. One of the violent EF-4 tornadoes that developed early in the event devastated the community of Washington IL.

The highly dynamic atmospheric conditions were forecast to develop several days prior to the event. Storm Prediction Center (SPC) products and analyses began targeting the outbreak area four days in advance. As the day approached, SPC outlooks ramped up from Slight Risk to Moderate Risk and eventually High Risk for a large portion of Illinois and Indiana. The advance warning of the potential severity of the event was highlighted by the local National Weather Service (NWS) outlooks and Impact-based Decision Support Services (IDSS), which included e-mail messages, conference calls and webinars. Media outlets aided in increasing public awareness by passing along the NWS outlooks. Post-event interviews confirmed that timely warnings received on NOAA weather radio, through local media outlets, and Wireless Emergency Alerts (WEA) on cellular phones, all played a role in keeping the fatalities at a very low number for such a high impact tornado outbreak.

This study will focus on the low level thermodynamic and wind shear profiles associated with the outbreak and discuss how they related to previous research on significant tornado days by Miller and Mann (2010). Their research suggests a distinct pattern in the surface to one kilometer hodograph curvature that may be indicative of potentially violent tornado days.

Investigation will be done on the potential role of radar “Reflectivity Tags” (Barker, 2006) detected in the near storm environment, both prior to tornado development in the Washington tornado supercell and also directly before the tornado intensified to produce EF-4 damage across much of Washington, IL. Reference will be made to research by Barker that suggests these Tags are caused by gravity waves, and their interaction with the storm may have been a significant player in the initial tornado formation and subsequent rapid intensification.

Additional analysis will be done concerning the WSR-88D Dual Pol Tornadic Debris Signature (TDS) during this event and the heights to which debris was lofted by the intense tornado and mesocyclone. Reference will be made to recent research by Entremont (2013) and Schultz, et al. (2012) on the possible operational utility of using TDS signatures in real time to infer not only tornado existence but also tornado intensity, especially in the absence of spotter reports. As a result, impact-based warnings could then include wording to heighten the awareness of the severity of the tornadic event, in the hopes of saving more lives.

The Tornado Outbreak of 17 November 2013

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The severe weather outbreak that occurred on 17 November 2013 produced 15 tornadoes in the County Warning Area (CWA) of the National Weather Service in Northern Indiana (IWX). While the damage resulting from these tornadoes were all rated between EF0 and EF2, it does rank as one of the largest tornado outbreaks in the number confirmed for a single day. Additionally, the 28 tornadoes that occurred in the state of Indiana this day was the largest outbreak for November in recorded history for Indiana, and the third largest outbreak in state history for any month.

A classic low CAPE/high shear environment was in place on this day as a vigorous negatively tilted shortwave trough tracked east-northeast toward the Illinois/Wisconsin border by late afternoon. An anomalously strong upper/mid-level jet (120kt at 500mb) undercut this upper wave with deep diffluent flow observed locally with the left exit region of the jet. This coupled with a 60-70kt low level jet supported strong cyclogenesis as the surface low deepened and tracked from eastern Iowa to Lake Superior. Convection fired along the prefrontal trough in advance of the attendant surface cold front across western Illinois by mid-morning and rapidly organized eastward into Indiana during the afternoon. The mesoscale environment was clearly supportive of severe thunderstorms with deep layer effective shear more than sufficient to support rotating updrafts. Line normal 0-3km bulk shear near 50kts was also supportive of mesovortex tornado formation in bowing segments. Slight backing of surface winds was noted which yielded 0-1km SRH values over $500 m^2/s^2$ and in combination with low LCL heights (<1000m) were significant factors in increasing the tornado potential. Discrete supercells developed from northern through central Illinois during the late morning hours. These storms exhibited strong rotational couplets and classic supercell radar signatures, quickly producing several large and violent tornadoes in central Illinois. As these storms raced northeast toward the Indiana state line at 60kts, they began to merge with other storms and formed the backbone of a larger scale QLCS. Numerous small scale circulations and embedded supercell structures were noted within this line as it entered into the western edge of the IWX CWA.

This presentation will examine some of the unique challenges that are faced in the warning decision making process involving tornado development that is commonly embedded within a QLCS. The application of research into the operational setting in formulating a conceptual model of storm structure, detailed analysis of radar and near-storm environment, and the effectiveness of Impact Based Warning templates will be examined along with some of the unique findings in the damage surveys following the event.

Diagnosing EF-Scale Potential Using Conditional Tornado Probabilities

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Results from a ground-breaking study by Smith et.al (2014) are used to derive an operational strategy for employing enhanced tornado damage threat tags in NWS IBW Tornado Warnings. Specifically, the Smith et. al. study compared maximum rotational velocity (Vrot) measured at the 0.5 degree WSR-88D elevation slice to maximum EF-scale damage observed from confirmed tornadoes in various convective modes (supercell, QLCS, etc.). Observations from over 4,000 tornadoes were included, creating a robust dataset that affords probabilistic approaches to diagnosing EF-scale potential in observed tornadoes. This presentation shows a methodology for developing operational Vrot thresholds for optimally employing the IBW "Considerable Damage Threat" tag in Tornado Warnings (i.e. EF2-5 tornadoes), and offers a strategy for working through inherent uncertainties in probability space.

Two Cases of Tornadic Wind Estimation and Implications for Impact Based Warnings

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Low level rotational velocity of two Quasi-Linear Convective System (QLCS) mesovortices (Trapp and Weisman 2003) occurring with separate QLCS events are investigated in conjunction with environmental Significant Tornado Parameter (Thompson et al. 2004) values to assess the likelihood of significant tornadic winds (i.e., EF-2 or greater) using the findings of Smith et al. 2012. The application of this methodology to National Weather Service Central Region Impact Based Warning decisions is then discussed.

The Use of GOES 7.4 µm Sounder Imagery for Severe Weather Detection: 2012 and 2013 Northeastern U.S. Examples

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With a substantial amount of forecaster training focused on radar and model data interpretation, the use of satellite data for hazardous weather operations can often be overlooked. For example, it has been shown that data from the GOES Sounder 7.4 µm channel can be useful for the detection of elevated mixed layers, which have a well-documented history of producing significant severe weather across the U.S. (Carlson et al. 1983; Ferrell and Carlson 1989; Banacos and Ekster 2010). During the recent convective season, several episodes of severe weather associated with elevated mixed layers occurred across the Northeastern U.S., and a few of these cases will be shown to emphasize the utility of using 7.4 µm imagery for severe weather operations.

In addition to the 2013 convective season, a significant severe weather episode developed across the BGM forecast area on 26 July 2012. On this day, 7 tornadoes were confirmed across the Southern Tier of central New York and northeastern Pennsylvania, with an EF-1 rated tornado occurring within the city limits of Elmira, New York. It will be shown that this event was associated with an elevated mixed layer which was readily identifiable on GOES 7.4 µm Sounder imagery. Furthermore, additional review of this event indicated that the developing convection initiated along the leading edge of the elevated mixed layer plume, in a well-pronounced gradient of highly unstable air to the south and more stable air to the north. It is believed that moist unstable air trapped below the elevated mixed layer was laterally transported north to an area where no capping existed aloft through a process known as “underrunning.” This process occurs when the boundary layer ageostropic wind component normal to the capping inversion increases due to the presence of a jetstreak induced direct thermal circulation aloft. While the topic of elevated mixed layers has recently gained renewed popularity; the concept of underrunning has largely been absent from recent scientific literature and as a result, the 26 July 2012 case will be presented to reinforce recognition and understanding of this process.

Avoiding Large, Sparsely Verified Severe Thunderstorm Warnings

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In 2008 the National Weather Service (NWS) began issuing storm based polygon warnings. Compared to county based warnings, polygons limit the warning to just the area threatened by severe weather. When communicated effectively, polygon warnings reduce the perceived false alarm area by excluding portions of counties where no weather threatens. Even so, for these warnings to be meaningful and elicit an appropriate response, most should end up verifying. Likewise, although just a single report verifies a polygon of any size, polygons should be sized appropriately for the severe weather that actually occurs. Sparsely verified large polygons are mostly large false alarms. While a lack of reports in portions of a polygon can be traced to multiple factors, one of course may be that no severe weather occurred in those areas. Especially in the case of large polygons, it is important to examine ways of better distinguishing between situations that will produce widespread severe weather and those that are more benign.

Many of the largest polygon warnings are issued in response to a perceived threat of widespread damaging winds from lines or clusters of storms. In some situations large polygons are quite appropriate, but many times a smaller and more targeted polygon would provide better service by focusing attention on the area most threatened. This presentation examines the frequency of large but sparsely verified severe thunderstorm warnings from NWS offices in the Great Lakes. It then reviews environmental factors associated with the threat of damaging wind events. Finally, it provides examples where a better understanding of the mesoscale environment and radar signatures might have given forecasters confidence to utilize smaller polygons that would have been a better fit to the reports actually received.

A National Weather Service Conundrum: Balancing Innovation and Standardization

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The National Academy of Public Administration (NAPA) performed a congressionally-mandated review of the National Weather Service (NWS) structure in May 2013. It found that one of the NWS's great strengths was its innovative workforce. The report, called *Forecast for the Future: Assuring the Capacity of the National Weather Service*, also found that unregulated research and development was resulting in overwhelmed systems and security risks. The NAPA Panel recommended that these problems be considered a very high priority, though it cautioned against suppressing innovation.

The NAPA report poses a difficult problem: How do we manage innovation without stifling it? If a balance between innovation and standardization must be achieved, then the NWS must begin to control some parts of the innovative process. This necessitates a broad scale NWS culture change. It is likely that by organizing efforts and providing innovation teams with some constraints, the NWS will improve standardization of services at minimal cost to innovation. This presentation and discussion will outline possible methods for achieving this goal.

Configuring AWIPS to Include Decision Support Events in Warnings

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Decision Support Services continue to take a larger role in day-to-day operations at the local National Weather Service Forecast Office. Previous attempts at including Decision Support Events directly in the warnings were undertaken by the Central Region WarnGen Tiger Team and included a selection to include a special heads-up for outdoor events. However, with an increased DSS role and a growing number of large events, keeping track of these events to include in our warnings has become increasingly difficult and time consuming. Several previous efforts have made all DSS events and large event venues available to AWIPS for inclusion in a warning. Unfortunately, these solutions would mention events or venues, even when no event was ongoing and made no discretion of attendance. In an attempt to improve upon these efforts, this project expands upon previous groundbreaking work performed by Doug Speheger, Evan Bookbinder and Mike Dangelo to allow adaptable, dynamic displays within AWIPS. By introducing date/time based logic, and WarnGen flagging, we have developed a solution that allows the integration of DSS events into AWIPS on a dynamic approach, and one that is expandable toward more novel housekeeping efforts, such as Google Calendar.

This presentation will focus on these issues and share feedback from Emergency Managers about the success of including these events directly in our warnings. In addition the criteria used to determine the level of service Decision Support Events receive will be explored.

Using GIS to enhance impact-based weather warnings

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Geographical information system can integrate meteorological hazard information with other data sets such as land use, population density and known infrastructure to assess community hazard exposure and potential impacts. WFO-GRR has begun a collaborative project with WFOBTV to develop GIS based risk assessments using a simple 5 color risk-based alert system to provide simple, clear, consistent, and actionable long-fused weather hazard information to a variety of users. Examples of current system prototyped at WFO-BTV (**WALS**) will be presented along with plans for further development.

Examining the land-lake-atmosphere interactions of the May 5, 2003 severe weather event over southwest Michigan

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Hydrology in the Great Lakes region is not fully understood, due in large part to the land-lake-atmosphere interactions and the mesoscale features associated with these interactions. These mesoscale features can produce precipitation and play an important role in the distribution of water in the region. During the late spring and summer months, the difference in temperature between the relatively colder lake surface and the warmer atmosphere typically results in a stabilization of the lower boundary layer. The temperature contrast between the lake surface and the warmer land mass can also allow for lake breezes to form in a manner similar to how sea breezes form in other coastal areas. While the majority of these features have been studied and are well documented, there are still several interactions between the lake surface and surrounding environments that have been observed, but the creation process is unknown.

The case examined in this study occurred in early May 2003, when a nearly stationary line of cumulus clouds formed several kilometers inland from Lake Michigan over southwest Michigan. These clouds eventually decoupled from the lake and evolved into a line of severe thunderstorms several kilometers inland, resulting in a rain shadow along the coast. The thermodynamic and dynamic structure of this system is explored through a 400m horizontal resolution Weather Research and Forecasting Model (WRF) simulation. This simulation is used to examine the mechanisms for the formation of the severe weather near the lakeshore. It is also compared with output from simulations run at horizontal coarser grid spacing to assess the sensitivity of the simulated convection to horizontal resolution in the model. Understanding this fine-scale feature could be important for both forecasting severe weather and evaluating future climate scenarios, as existing climate models may not accurately represent the land-lake-atmosphere interaction in the Great Lakes region.

A historical-analog-based severe weather checklist for central New York and northeast Pennsylvania

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This presentation describes an operational severe weather checklist developed at the National Weather Service Weather Forecast Office (WFO) in Binghamton, New York (BGM). The checklist contains two sections: a traditional severe weather parameter data entry section, and a historical analog retrieval section. Parameters on the checklist are related to the mean sea-level pressure and 500 hPa geopotential height pattern, stability, vertical wind shear and moisture. The analog retrieval portion of the checklist returns information on five historical events that are analogous to current conditions, based on data entered into the checklist. An example of the utility of the checklist is shown for a major severe weather event on 28 April 2011, which featured numerous severe weather reports in the WFO BGM county warning area, including seven tornadoes. The top analog retrieved by the checklist for this case was associated with a major tornado outbreak, and another analog also featured multiple tornadoes.

Results from a verification study on the similarity between 81 test events and corresponding analogs are shown. High correlations were found between values of convective available potential energy (CAPE) and bulk shear in the test cases vs. corresponding values of those parameters in the analogs. A comparison of radar imagery and severe weather reports associated with the test cases and corresponding analogs indicate that the system can help forecasters to anticipate convective mode, and to discriminate between major and null severe events. The system also appears to provide useful guidance on the potential for tornadoes, and may alert forecasters to the potential for convective flash flooding and whether events will be dominated by wind or hail.

Analysis of Northwest Flow Severe Weather Events Over North Central Upper Michigan

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Over the last several years, severe convective weather over north central Upper Michigan has been most significant in northwest flow conditions. In fact, some of the severe thunderstorms have resembled typical supercell thunderstorms normally seen in the central U.S. plains. It is believed that the combination of the larger scale flow pattern and local effects, such as topography and lake breeze boundaries, is largely responsible for this local area of enhanced severe weather. However, the exact reasoning has not been studied in depth. Using observational and radar data, as well as numerical weather prediction (NWP) model datasets, analysis of the relationship between the larger scale and small scale patterns will be analyzed. The information gained from this research will give local meteorologists better tools to better forecast this subtle, yet critical, severe weather pattern for Upper Michigan.

The Utility of Considering Dual-Polarization Radar Signatures in the Tornado Warning Process

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Prior research (Crowe et al. 2012) has shown that the combined radar signatures of differential reflectivity (Zdr) and specific differential phase (Kdp) helped identify regions of enhanced lower-tropospheric shear/tornadic potential, within varied thunderstorm environments across the southern United States in 2010-2011. The specific radar signatures included an arc-shaped region of enhanced Zdr, typically located along the front inflow side of the storm; as well as an enhanced area of Kdp, typically located deeper into the mesocyclone, and left of the aforementioned Zdr arc/maximum.

Other earlier work (Kumjian and Ryhkov 2007, 2008a, and 2009; Romine 2008; Crowe 2010) demonstrated that the physical reasoning for the development/locations of Zdr arcs and Kdp maxima involved preferential drop size sorting. Conceptually, both relatively high values of Zdr and low values of Kdp on the forward (typically eastern) side of the mesocyclone imply a smaller concentration of large rain drops. Such large drops would tend to fall more rapidly, thus decreasing their residence time in the storm. Conversely, both relatively high values of Kdp and low values of Zdr imply a higher concentration of smaller rain drops. Such smaller drops would have a greater residence time in the storm, thus having a better opportunity to be advected by the strongly sheared flow into the rear (typically western) portions of the mesocyclone.

Based on the initially promising results (Crowe et al. 2012), a number of events in the Northeastern United States featuring favorable synoptic environments for tornadic supercells, in which tornado warnings were issued and/or tornadoes occurred, were interrogated. For these cases, qualitative storm-scale assessments were made on the relative positions of Zdr arcs/maxima versus Kdp maxima, and also specific separation distances in nautical miles (nmi) between the two. For tornadic storms, an evolution featuring a separation between Zdr arcs/maxima and Kdp maxima, with the Kdp maxima typically juxtaposed to the rear/left of the Zdr arcs/maxima was quite common. For non-tornadic storms, Zdr and Kdp maxima were either collocated for the life cycle of the mesocyclone, or the Kdp maxima were displaced slightly to the right/eastern sides of Zdr maxima. These preliminary results favorably match those demonstrated across Alabama and the Tennessee Valley region (Crowe et al. 2012).

An Overview of the 31 May-1 June 2013 Heavy Rain/Flash Flood Event across Northern Indiana

Nick Greenawalt,
NOAA/National Weather Service
North Webster, Indiana

On the evening of 31 May 2013, a mesoscale convective system (MCS) developed across central Illinois and tracked east into northern Indiana. This system produced heavy rainfall across the southern half of the NWS Northern Indiana county warning area (CWA). As this system tracked east across northern Indiana, it entered an unfavorable wind shear environment and became increasingly disorganized and weaker. The weakened system produced a west-east oriented outflow boundary across the south-central portion of the CWA, and the synoptic pattern in place across the region allowed additional convection to fire along and just north of this boundary. Thunderstorms and heavy rainfall continued to train over the same area for several hours into the overnight, before another MCS originating across northern Missouri tracked east across the southern portion of the CWA early on the morning of 1 June 2013.

The axis of heaviest rainfall from this event was located along and just south of the U.S. 30 corridor in northern Indiana, from near Rochester, Indiana to the Fort Wayne, Indiana metro area. Rainfall amounts along this axis ranged from 3 to 6 inches, with significant flash flooding reported across the area. The Fort Wayne metro area was impacted the most by flash flooding, where many roads became inundated, resulting stranded cars and the need for water rescues. Spy Run Creek (SPYI3) near downtown Fort Wayne, a location prone to flash flooding, reached a record crest of 14.57 feet in a little over 6 hours after the heavy rainfall began.

This presentation will examine the cause and impact of this flash flooding event by looking at several factors, including the synoptic and mesoscale environment, antecedent hydrologic conditions, and the effects of the topography, hydrology, and urbanization of the Fort Wayne area. The performance of dual-pol versus legacy precipitation algorithms will also be discussed, as this was one of the first short duration heavy rainfall events to impact the local area following the dual-pol upgrade of the KIWX WSR-88D in February 2013.

A Look Back at the Historic July 28, 1949 Marquette County Flood

Steven Fleegel and Michael Dutter
NOAA/National Weather Service
Marquette, MI

During the early evening hours of July 28, 1949, thunderstorms produced heavy rainfall across portions of Marquette County, Michigan with up to 5.35 inches of rain falling in a 2 hour period (less than a 1/1000 annual exceedance probability). This heavy rainfall caused localized flooding of streams and businesses, washed out numerous roadways across the county, and produced hundreds of thousands of dollars (in 1949 dollars) of damage. In an effort to determine the extent and rarity of the rainfall, an analysis of Cooperative Observer data from across the region was performed. In addition, an assessment of the meteorological conditions that led to the historic event will be completed, including surface observations, upper air observations, and the utilization of the 20th Century NCEP-NCAR Reanalysis. This reanalysis data will also be used to initialize a high resolution Weather Research and Forecasting (WRF) Advanced Research WRF (ARW) model run in an attempt to provide further detail on what occurred during that summer day.

Environment Canada and the TORONTO 2015 Pan Am / Parapan Am Games (TO2015)

Arnold Ashton
EC/OSPC
Toronto, ON

In the summer of 2015, Toronto is hosting the Pan Am and Parapan Am Games (TO2015), the second-largest world multisport games after the Summer Olympics. Environment Canada is required to support the safety and security of Canadians and participants during the Games by providing a 24/7, dedicated, venue- specific weather warning service. To do so EC will extend the production of weather warnings to 20 venues or venue clusters using current EC criteria and standards for dissemination to Essential Federal Services, Emergency Management Ontario, and the TO2015 organization. A weather consultation service will be provided from the TO2015 Main Operations Centre in downtown Toronto.

To deliver these weather services, EC will showcase an enhanced environmental monitoring network to provide high impact weather surveillance for the decision making by EFS, other public authorities, and the TO2015 organization.

This talk will provide an overview of the TO2015 Games, a description of the enhanced weather monitoring including new technology, as well as some of the forecasting challenges.

Learning Social Media at NWSFO Grand Rapids

Ernest J. Ostuno
NOAA/National Weather Service
Grand Rapids, Michigan

A three-year review of Facebook, Twitter and Youtube activity at our office is presented, showing what we learned in terms of presenting content, answering feedback and building an audience. Future strategies are also presented, with an emphasis on how to best communicate hazardous weather information through the various outlets of social media.